Gastrointestinal and Biliary Point-of-Care Ultrasound

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KEYWORDS

• Point of care ultrasound • Biliary ultrasound • Intestinal ultrasound • Pediatrics • Emergency medicine

KEY POINTS

- Point-of-care ultrasound (POCUS) can be used to diagnose a variety of bowel and biliary pathologies such as intussusception, appendicitis, small bowel obstruction, and cholecystitis.
- POCUS has been shown to be accurate and to improve emergency department length of stay for various bowel and biliary pathologies.
- Scanning protocols and techniques vary across bowel applications, depending on the pathology of interest.
- Graded compression is a key technique in displacing bowel gas when assessing the bowel.
- Performing POCUS of the gallbladder may require varied approaches to optimize ultrasound views.

Video content accompanies this article at http://www.emed.theclinics.com.

INTRODUCTION

Point-of-care ultrasound (POCUS) has been used for the diagnosis of many different intra-abdominal pathologies in both adults and children. POCUS has been well studied to have excellent diagnostic accuracy for multiple conditions, including intussusception,[1,2] appendicitis,[3] small bowel obstruction (SBO),[4,5] and cholecystitis.[6] In addition, POCUS has been shown to improve patient-centered metrics, including decreasing length of stay (LOS) for certain bowel and biliary complaints.[7–9] In this review, the authors discuss gastrointestinal and biliary POCUS applications.

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APPROACH

Anatomy

In the normal bowel, there are 5 distinct layers of bowel wall with alternating hyperechoic and hypoechoic appearance on ultrasound. This distinctive alternative appearance is often known as the "gut signature." The 5 layers from internal to external are superficial mucosa, muscularis mucosa, submucosa, muscularis propria, and serosa (Fig. 1). Depending on the image quality of the POCUS, not all the layers may be easily visualized.

Technique

The exact scanning protocol will vary depending on the pathology for which the patient is being evaluated. However, typically the patient is placed in a supine or lateral decubitus position. As the bowel can often be filled with air, an important technique to utilize is graded compression. Graded compression consists of slowly and gently increasing pressure with the ultrasound probe on the bowel to help displace air out of the way of the probe. The gentle increase in pressure also helps to prevent or minimize patient discomfort.

A curvilinear, low-frequency probe is often used for adult patients for initial scanning, and this can be combined with a wide-footprint, linear, high-frequency probe to increase image resolution once an area of interest is identified. In young, pediatric patients, a wide-footprint, linear, high-frequency probe is often preferred.

DISCUSSION

Hypertrophic Pyloric Stenosis

Background

Hypertrophic pyloric stenosis (HPS) occurs when the gastric pylorus becomes hypertrophied and obstructs passage of stomach contents from exiting the stomach. It is a common cause of intestinal obstruction in infants presenting to the emergency department. POCUS has been shown to have excellent diagnostic accuracy with a recent meta-analysis showing high sensitivity (97.7%) and specificity (94.1%) of POCUS for HPS.[10] Furthermore, POCUS for HPS has been shown to decrease length of stay for patients with suspected HPS.[8]

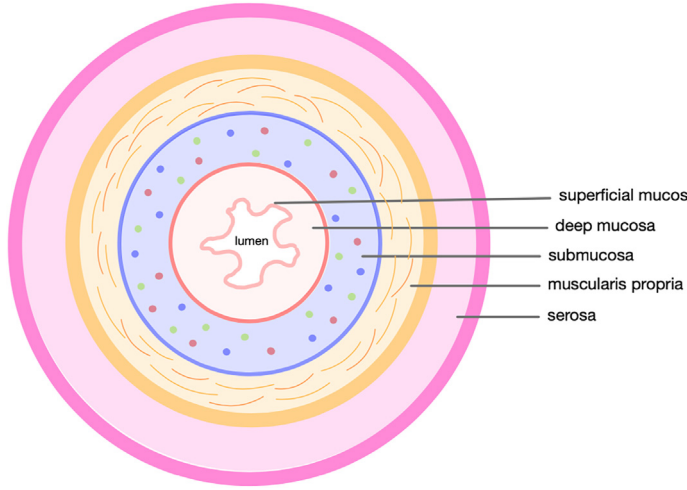

Fig. 1. Layers of bowel wall.

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Technique

For the scanning technique, the patient is placed supine or in a decubitus position and a wide-footprint, linear probe is used to image the subxiphoid area. Then the probe is maneuvered to the right, tracing the gastric wall until the pylorus is identified in the long axis. A muscle width of greater than 3 mm is considered positive for HPS (**Fig. 2**, Video 1), while varying cutoffs from greater than 14 to 17 mm have been used for channel length.[11]

Intussusception

Background

Ileocolic intussusception is the most common cause of bowel obstruction in children under 3 years of age.[12] It occurs when one part of the bowel telescopes into another part of the bowel. Typically, ileocolic intussusception (when the ileum telescopes into the colon) is the diagnosis of interest as these are considered emergencies that require emergent reduction, usually by air enema. There have now been several studies indicating that POCUS for ileocolic intussusception has excellent diagnostic accuracy comparable to radiology-performed studies.[1,2] Indeed, a recent meta-analysis showed sensitivity of 95.1% and specificity of 98.1% of POCUS for intussusception.[1] POCUS also improves patient-centered metrics for patients with suspected intussusception, including decreased time to reduction and length-of-stay.[9]

Technique

On ultrasound, an ileocolic intussusception in transverse appears as a "target" lesion (**Fig. 3**, Video 2) or a "sandwich" sign in the longitudinal view. In order to identify the intussusception, the entire colon should be imaged, often using a wide footprint linear

Fig. 2. Hypertrophic pylorus with muscle width measuring greater than 3 mm.

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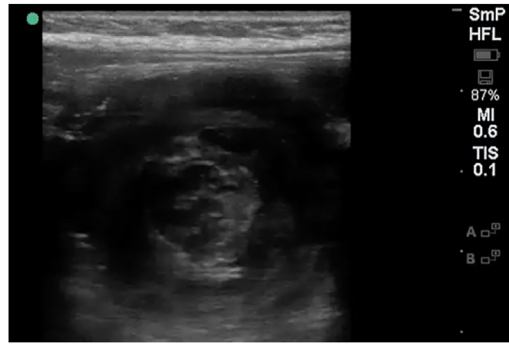

Fig. 3. Intussusception with target sign.

probe.[13] The patient should be positioned supine, and the probe placed in the right lower quadrant (RLQ) with the probe marker toward the patient's right. The psoas muscle and right iliac artery and vein are identified as landmarks with the bladder noted medially. Graded compression is then performed with slow and steady pressure to displace bowel gas. The colon is subsequently traced from RLQ to right upper with the liver and gallbladder identified. The probe is then rotated with the probe marker facing the patient's head and moved across the transverse colon to the left upper quadrant. The probe is then rotated back to its original orientation and the left side of the abdomen is evaluated down the descending colon.

Ileocolic intussusceptions usually will appear on the right side of the abdomen, given the location of the ileum and cecum, and have a diameter of at least 2.5 cm in the transverse view.[14] Other types of intussusception, such as small bowel–small bowel intussusception, can also appear as target/sandwich lesions but tend to be smaller (<2.5 cm) and may not be located in the right side of the abdomen.[14] The distinction between ileocolic and small bowel–small bowel intussusception is important as the latter often can resolve without procedural intervention.[14]

Appendicitis

Background

Acute appendicitis is one of the most common surgical emergencies, but its diagnosis is often dependent on computed tomography (CT). Ultrasound has the benefit over CT scanning of lack of ionizing radiation, which is especially important in children. A systematic review and meta-analysis of POCUS for appendicitis by emergency clinicians showed a sensitivity of 91% and specificity of 97%.[3] The incorporation of POCUS into the evaluation of appendicitis has been shown to reduce CT use[15] and Emergency Department (ED) length of stay.[7] However, patient factors, disease progression, and the sonographic appearance, orientation, and location of the appendix can make appendiceal sonography complex.[16,17] Further, an uninfected appendix can be difficult to identify and differentiate among bowel loops causing uncertainty with what to make of equivocal studies that do not directly visualize a normal appendix. While studies with non-visualized appendix present a diagnostic dilemma, absence of secondary signs of inflammation on ultrasound in the proper clinical scenario may decrease concern for appendicitis.[18,19]

Technique

The POCUS technique for evaluating the appendix involves evaluating the RLQ with a linear or curvilinear probe depending on the size and habitus of the patient. Three

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techniques for approaching POCUS for appendicitis include identifying the point of maximal tenderness, tracing landmarks (eg, iliopsoas muscle, rectus muscle, and iliac vessels), and protocolized evaluation of the entire RLQ.[20,21] For all techniques, the patient should be positioned supine. The point of maximal tenderness technique involves placing the probe over the most tender area of palpation in the RLQ and slowly applying gentle pressure to identify the above landmarks and look for an inflamed appendix. The tracing landmarks technique starts with the probe in the RLQ of the abdomen and inferior to the iliac crest. The probe is then moved progressively cephalad identifying the cecum followed by the iliopsoas, rectus muscle, and iliac vessels. The appendix may appear in the triangle formed by these structures. The protocolized evaluation of the RLQ starts with the probe in the transverse position at the level of the umbilicus moving laterally, caudally, medially, and then back cephalad in a rectangular pattern surveying the landmarks identified earlier.

On ultrasound, a normal appendix appears as a blind-ending tubular structure, which initiates from the cecum and exhibits no peristalsis. Appendicitis is characterized as a noncompressible appendix with a diameter greater than 6 mm (**Fig. 4**).[22] Other secondary signs of appendicitis include peri-appendiceal free fluid, hyperechoic mesenteric fat, appendicolith (**Fig. 5**), increased blood flow with hyperemia known as the "ring of fire" surrounding the appendix on color Doppler mode, or a complex RLQ mass, suggestive of ruptured appendix.[22]

Diverticulitis

Background

In North America, CT is the preferred imaging modality for patients with suspected acute colonic diverticulitis (ACD) because of its high sensitivity and specificity.[23] Utilizing ultrasound as the first diagnostic study for ACD is common in Europe, with

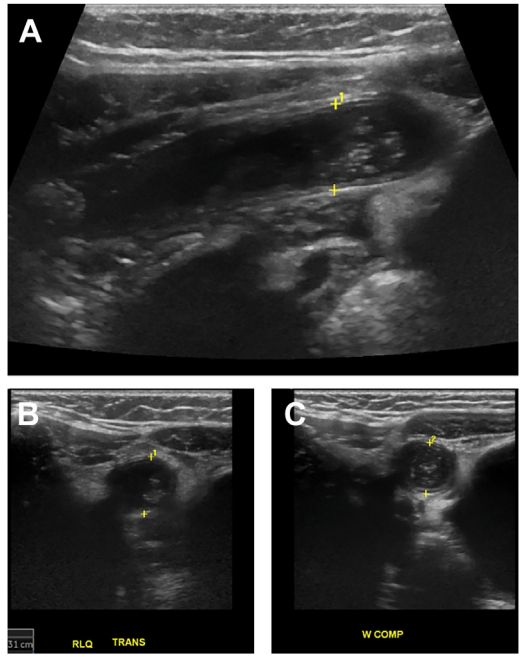

Fig. 4. Appendicitis in sagittal (*A*), transverse (*B*), and with compression (*C*).

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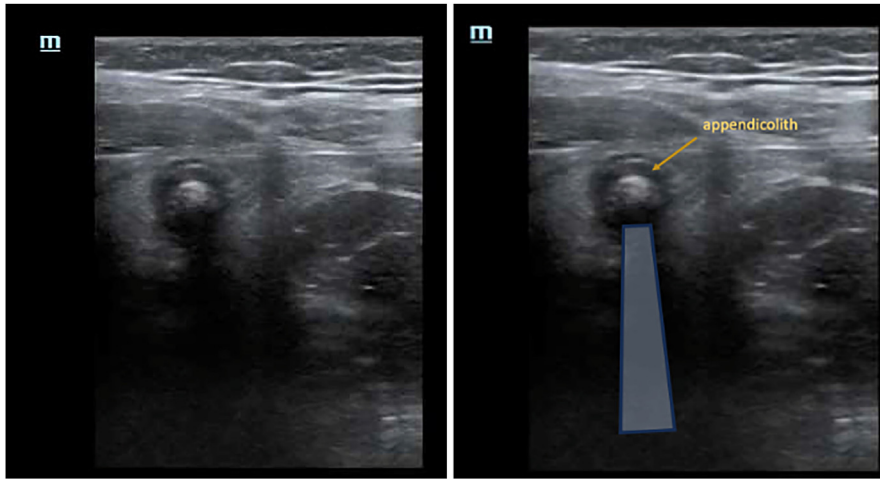

Fig. 5. Shadowing appendicolith with (*right*) and without (*left*).

the European Federation of Societies for Ultrasound in Medicine and Biology recommending that gastrointestinal ultrasound be the preferred imaging to diagnose uncomplicated ACD without CT.[24] Reports in the literature cite similar diagnostic performance between CT and ultrasound for uncomplicated ACD, with ultrasound less sensitive for detecting complicated ACD.[25–29] Recent prospective studies demonstrated POCUS had a sensitivity of 92%–95% and specificity of 76%–97%, respectively, in evaluating for uncomplicated ACD.[30,31]

Technique

Ideally, the patient should have a full bladder to optimize the view of sigmoid colon.[24] The patient-identified point of maximum tenderness is a good place to begin, with the graded compression technique to best identify structures. The diagnosis of noncomplicated ACD is suggested by the following: (1) thickened bowel wall measuring greater than 5 mm; (2) presence of diverticula with focal outpouching or discontinuity of the bowel wall; (3) noncompressible pericolic fat inflammation with a hyperechogenic halo surrounding the bowel serosa; and (4) sonographic tenderness to compression,[28] as seen in **Fig. 6** and Video 3. The diagnosis of complicated ACD is suggested by the presence of (1) pericolic abscess (ie, a pericolic fluid collection); (2) intraperitoneal free fluid; or (3) intraperitoneal free air.[28]

Bowel Obstruction

Background

Bowel obstruction occurs with disruption of the normal passage of intestinal contents, which can be due to a mechanical or functional cause. It is regularly encountered in emergency departments, as 2% of all patient presentations with abdominal pain.[32] Bowel obstruction requires timely diagnosis, as ongoing obstruction can lead to complications such as bowel ischemia or bowel perforation requiring emergent surgical intervention. POCUS has a sensitivity of 83% to 92% and specificity of 93% to 96% in the evaluation of SBOs.[4,33]

Technique

Specific diagnostic criteria for detecting SBO vary across studies.[34–36] Sonographic features in diagnosing SBOs have demonstrated different diagnostic performance.

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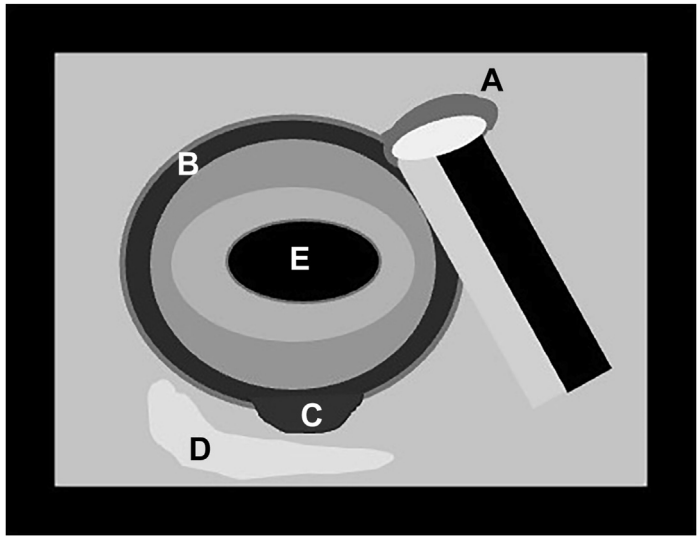

Fig. 6. Schematic of acute diverticulitis findings on ultrasound, (A) Diverticulum with fecolith and associated mixed shadowing, (B) thickened muscularis propria, (C) diverticula with associated hyperemia (D) in the surrounding tissues, and (E) bowel lumen.

In a recent study evaluating for SBO with POCUS, bowel diameter greater than 2.5 mm demonstrated 87% sensitivity and 87% specificity, while abnormal (absent or to-and-fro) peristalsis demonstrated 82% sensitivity and 85% specificity.[35] The presence of a transition point is 82% sensitivity and 98% specificity, while free fluid had 82% sensitivity and 93% specificity, and bowel wall edema, which can be marked by the visualization of jejunal crescenteric folds known as plicae circulares, had 76% sensitivity and 93% specificity for diagnosing SBO (Video 4).[35] A transition point, if found, can help distinguish an SBO from an ileus. On ultrasound, it appears as an area of decompressed bowel adjacent to dilated bowel.

Comparatively, large bowel obstructions are rarer than SBOs. Large bowel obstructions have similar sonographic features as SBOs, including dilatation, abnormal peristalsis, free fluid, and typically have more marked dilatation, greater than 5 cm in diameter.[37] The haustra of the large intestine can become more prominent with bowel wall edema and luminal dilation and tend to be spaced further apart than the plicae circulares of the small bowel.[38]

Hernia

Background

A hernia occurs when an organ or tissue protrudes through a weak area in the fascial and muscle layers. Two primary areas that abdominal hernias occur involve the inguinal region or anterior abdominal wall. Hernias can contain bowel, mesenteric fat, and fluid.

Technique

Despite different locations, the approach to imaging hernias with ultrasound is similar.[39]

The probe is placed directly over the area of concern. The dynamic nature of POCUS provides important information in evaluating a hernia.[40] Specifically, obtaining

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and comparing images with the patient in different positions (eg, standing and supine) and with and without the patient performing a Valsalva maneuver provide key information, as the hernia can be directly visualized and can be assessed for tenderness and reducibility. A hernia might not be visualized without the Valsalva manuever[41] or might be reducible in one position and not the other. A simple hernia is seen with POCUS as a defect in the peritoneal layer with protrusion of intra-abdominal contents (**Fig. 7**). Strangulation can occur when bowel is present in the hernia but circulation is cut off to the bowel tissue. Strangulation is marked by thickened hernia wall, thickened bowel wall internal to the hernia, and echogenic fat surrounding the hernia.[42]

Pneumoperitoneum

Background

Pneumoperitoneum is a rare yet serious cause of abdominal pain that most commonly results from a perforated hollow viscus and is associated with high rates of morbidity and mortality.[43] A number of studies and case reports have highlighted the rapid detection of pneumoperitoneum with POCUS and the superior diagnostic sensitivity of ultrasonography relative to plain radiography.[44]

Technique

As air typically collects in the least dependent area, the patient should be scanned first in the supine position using a linear (preferable due to higher resolution in the near field where air accumulates) or curvilinear probe in both the right upper quadrant and midline of the abdomen. The patient should then be turned to the left lateral decubitus position for better visualization of the right upper quadrant.[45] This allows for better visualization of the interface between the anterior abdominal wall and the liver.

In the abdomen, tissue-air interfaces are common, given the normal presence of air within the bowel, often resulting in multiple horizontal, repeating, echogenic artifacts, particularly over the colon. Thus, it may be difficult to differentiate physiologic intraintestinal air from pathologic free abdominal air. To differentiate between the 2 entities, 3 main sonographic signs have been described.[46] The first results from the appearance of the free air interface with the peritoneal lining creating a characteristic thick

Fig. 7. Umbilical hernia.

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hyperechoic line which is referred to as the enhanced peritoneal stripe sign (EPSS).[46–48] Second is the shifting phenomenon that occurs as the patient moves from one position to another causing the free to travel to the least dependent position. This results in shifting of the EPSS from the anterior abdomen to the lateral aspect of the liver when the patient repositions from supine to the left lateral decubitus position.[47] Lastly, ring down artifact may be seen as the result of air-to-soft-tissue interface causing posterior reverberation artifacts (**Fig. 8**).[46–48]

Biliary Ultrasound

Background

Sonographic evaluation of the hepatobiliary system is often considered the first-line imaging for right upper quadrant pain.[49] Biliary POCUS performed by emergency physicians was found to predict surgical management decisions, with only a 10% change in surgical plan with the addition of a radiology-performed ultrasound.[50] A recent systematic review found emergency physicians-performed POCUS to have pooled sensitivity 71% and specificity 94% in diagnosing cholecystitis.[51]

Technique

The intercostal approach may be useful for patients who have abdominal tenderness, as it avoids contact with the abdominal wall (**Fig. 9**). The xiphoid process is identified, and the probe is placed 7 cm lateral to midline xiphoid process in the intercostal space of the right upper abdomen, in a sagittal orientation. In smaller and pediatric patients, the probe can be placed in the midclavicular line, and a smaller footprint probe can be used. In the subcostal approach, the probe is placed along the right costal margin in

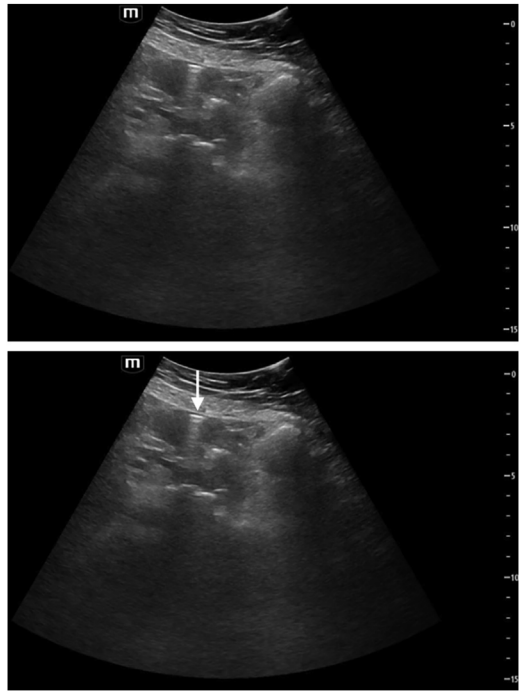

Fig. 8. Pneumoperitoneum. (Image courtesy: Michael Gottlieb, MD.)

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Fig. 9. X minus 7 technique. Academy of emergency ultrasound. Visited October 24, 2023. Aeus image bank: Biliary. Des Plaines, IL: Society for academic emergency medicine. saem.org.

the upper abdomen, with the indicator pointing to the left shoulder in an oblique orientation (**Fig. 10**). The lateral to anterior sweep technique (**Fig. 11**) is utilized as a rescue view for either the intercostal or subcostal approach. The probe is placed in a coronal plane in the mid-axillary line in the expected position of the right seventh intercostal space and then sweeps anteriorly seeking the gallbladder, if not visualized, then the probe moves in a lateral to medial direction, coming anterior onto the abdomen.

Positioning the patient in the left lateral decubitus position can help bring the gallbladder more anterior as well as drop some of the bowel gas out of view. Directing the patient to take a deep breath can lower the diaphragm and the gallbladder, which may also improve image acquisition. Furthermore, tense abdominal musculature can contribute to difficulty compressing and displacing bowel gas. Bending the patient's knees can help relax some of the abdominal muscles to optimize imaging.

Once identified, the view of the gallbladder can be optimized into the classic orientations of the "exclamation point" sagittal view (**Fig. 12**) and the rounded transverse view (**Fig. 13**) by rotation, tilt, and rocking probe movements. The gallbladder can vary in its appearance, with septations or folds present.

Fig. 10. Subcostal technique. Academy of emergency ultrasound. Visited October 24, 2023. Aeus image bank: Biliary. Des Plaines, IL: Society for academic emergency medicine. saem.org.

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Fig. 11. Coronal lateral technique. Academy of emergency ultrasound. Visited October 24, 2023. Aeus image bank: Biliary. Des Plaines, IL: Society for academic emergency medicine. saem.org.

The gallbladder wall should be assessed in the transverse gallbladder orientation, with attention to the anterior gallbladder wall and along the liver interface, to avoid the effect of posterior acoustic enhancement. The upper limits of normal gallbladder wall thickness are traditionally taught as 3 mm, though a retrospective study found normal gallbladder walls in healthy individuals ranged from 1 to 4.2 mm in thickness.[52] The gallbladder wall can thicken in reaction to local or intrinsic inflammation or from systemic processes. A diffusely thickened gallbladder wall is observed in patients with cirrhosis, heart failure, or sepsis, or in patients with local inflammatory processes of the adjacent pancreas, colon, or kidney, as well as with acute cholecystitis.[53] Further, gallbladder adenomyomatosis is a benign process that gives the appearance of thickened gallbladder wall due to bile-filled pockets in the wall, found incidentally in about 9% of patients.[54] Additionally, the gallbladder wall can appear falsely thickened when the gallbladder is contracted, such in a postprandial state (Video 5).

The common bile duct (CBD) is the next area of interest and is observed often as part of the portal triad, "Mickey Mouse" sign. In the transverse orientation, it is observed as a small round anechoic structure anterior and lateral to the portal vein with the hepatic artery medial to it, both also in transverse rounded orientation (**Fig. 14**). The CBD does not have blood flow, thus applying color Doppler to portal triad structures to evaluate for the presence of flow can help delineate the CBD from the adjacent, similarly sized vascular structures. In longitudinal orientation, the CBD appears as a thin tubular structure, parallel and anterior to the tubular portal vein, which is seen parallel and anterior to the tubular inferior vena cava, creating the appearance of stripes. The cystic duct can also be visualized prior to joining the common hepatic duct to form the CBD. The small cystic duct is sometimes confused with the neck of the gallbladder and is more easily visualized when an obstructing stone is present.

Cholelithiasis typically appears as echogenic structures with anechoic posterior shadowing within the gallbladder or ductal structures (Video 6). They can vary in number, size, and composition. There is evidence that larger cholelithiasis predispose patients for gallbladder carcinoma.[55] Usually, the gallbladder neck is the most dependent part of the gallbladder when a patient is supine. When cholelithiasis is suspected, it is helpful to reposition the patient to the left lateral decubitus position to determine whether the structures of interest are mobile, immobile, or tethered. Cholelithiasis immobile in the gallbladder neck has an increased risk of developing

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Fig. 12. Sagittal view of the gallbladder.

cholecystitis.[56] The wall-echo-shadow sign occurs when a gallbladder is contracted with a stone in place (**Fig. 15**).

Biliary sludge can also be found within the gallbladder, with or without cholelithiasis, and appears as an echogenic fluid within the gallbladder (**Fig. 16**). Polyps are structures that form along the gallbladder wall and can be mistaken for cholelithiasis but are found to be tethered to the wall when a patient is repositioned and are less hyperechoic in appearance compared to cholelithiasis.[57]

The "Sonographic Murphy's sign" refers to maximal tenderness with compression with the ultrasound probe while the gallbladder is in view. It is thought to be highly specific for cholecystitis when cholelithiasis is present, even when analgesia is given.[58] Sonographic findings in acute cholecystitis include cholelithiasis with pericholecystic fluid, gallbladder wall greater than 3 mm, biliary distension, and the Sonographic Murphy's sign (Video 7).[59] Echogenic foci with dirty shadowing along the gallbladder wall suggest emphysematous cholecystitis from gas-forming bacteria, which carries a high mortality rate (Video 8).[60] In contrast, acalculous acute cholecystitis is an acute inflammatory biliary process without cholelithiasis, associated with critical, viral, or chronic illnesses.[61,62] Thickened gallbladder wall and pericholecystic fluid are common findings in acalculous cholecystitis.

Fig. 13. Transverse view of the gallbladder.

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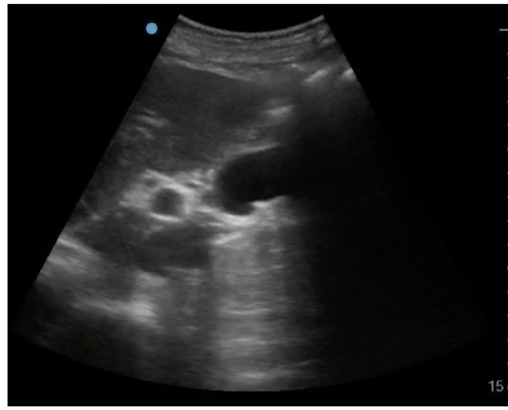

Fig. 14. Portal triad: Portal vein, common bile duct, hepatic artery.

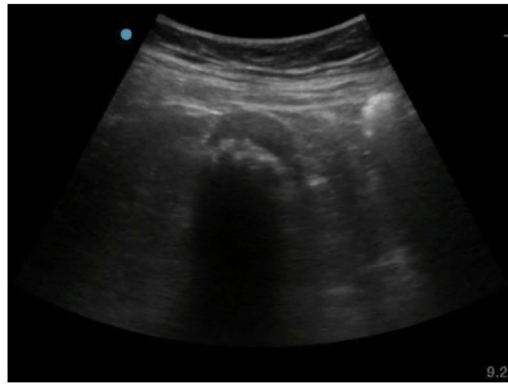

Fig. 15. Wall Echo Shadow Sign. The stones are near the gallbladder wall and the stones' associated acoustic shadow block visualization of the rest of the gallbladder.

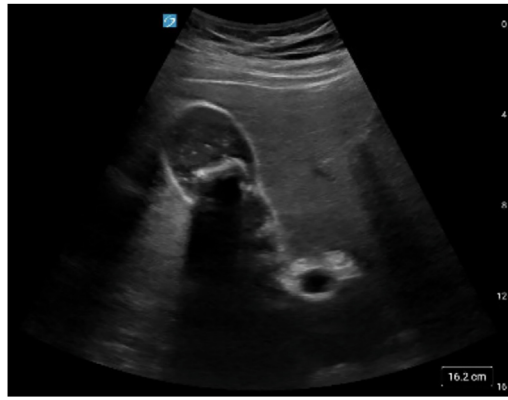

Fig. 16. Biliary sludge and cholelithiasis.

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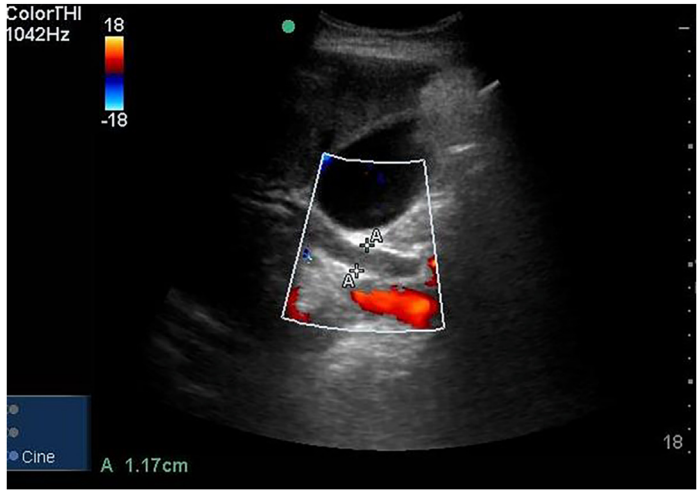

Fig. 17. Dilated common bile duct.

Cholelithiasis that passes through the gallbladder can become lodged in the CBD, is known as choledocholithiasis. Sometimes the obstructing stone is not visualized with overlying bowel gas; however, dilatation of the duct can be seen on ultrasound. The CBD can normally be larger after cholecystectomy or advancing age, with a study demonstrating that the CBD size is 3.1 $\pm$ 0.9 mm in patients younger than 50 years and 4.2 $\pm$ 1.2 mm in patients older than 50 years, showing that the CBD enlarges 0.04 mm/year, with upper limits of 8.5 mm for elderly patients.[63] The CBD size varies in children with one report noting upper limit of normal was 1.8, 2.7, and 4.2 mm for children younger than 1 year, between 1 and 10 years, and older than 10 years, respectively.[64] The CBD is most accurately measured between the inner walls of the duct while in the longitudinal orientation (Fig. 17).

SUMMARY

POCUS has multiple applications in the evaluation of gastrointestinal and biliary emergencies including HPS, intussusception, appendicitis, SBO, diverticulitis, hernias, pneumoperitoneum, cholecystitis, and other biliary pathologies. POCUS can accurately diagnose pathology, save time, reduce radiation exposure, and thus improve the quality of care for patients affected by these conditions.

CLINICS CARE POINTS

- Studies have demonstrated POCUS diagnosis of various bowel and biliary pathologies can shorten emergency department length of stay.
- There is limited evidence for use of POCUS in identifying HPS in infants with a pylorus cutoff width greater than 3 mm and channel length greater than 14 to 17 mm.
- POCUS demonstrates excellent diagnostic accuracy for the identification of intussusception, which can appear as a "target" or "sandwich" sign.
- POCUS has excellent diagnostic accuracy for the identification of appendicitis.
- POCUS has high sensitivity and negative predictive value for uncomplicated ACD.

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- POCUS in the evaluation of SBOs has been shown to have high sensitivity and specificity.
- POCUS can rapidly detect pneumoperitoneum and has better diagnostic sensitivity compared to radiography.
- POCUS findings in acute cholecystitis include cholelithiasis with pericholecystic fluid, gallbladder wall greater than 3 mm, biliary distension, the sonographic Murphy's sign, and/or hyperemia surrounding the gallbladder.

DISCLOSURE

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SUPPLEMENTARY DATA

Supplementary data related to this article can be found online at https://doi.org/10.1016/j.emc.2024.05.006.

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